

## PATENT SPECIFICATION

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## PROVISIONAL SPECIFICATION

## Solenoid Devices

I, MALCOLM CHRISTIE BRITAIN, a British Subject, of Kidbrooke, Ridge Way, High Wycombe, Buckinghamshire, do hereby declare the nature of this invention to be as follows:—

This invention relates to improvements in solenoid devices. It is a common requirement in a wide variety of appliances that a linear movement shall be imparted to a movable body such as a plunger, piston, core-piece, valve element, projectile or the like. In particular a movable body of the form of a prism, cylinder or ball may have to be moved within a chamber of uniform cross-section such as a hollow cylinder whose axis is straight or curved. The required motion may be (and generally is) a reciprocation but in some instances the movable body may be a projectile which has to be discharged from its chamber.

One object of this invention is to utilize electric solenoids to control the linear movement of a body (containing magnetic material) through a long path. Another object is to subject the movable body to acceleration.

This invention consists of a solenoid device in which a body (containing magnetic material) such as a plunger, piston, core-piece, valve element, projectile or the like is movable in or through a chamber or channel such as a hollow cylinder whose axis is straight or curved, said chamber or channel being embraced by a plurality of electric solenoids arranged in tandem in combination with switch means for energising said solenoids in succession so that said movable body receives in succession electromagnetically a plurality of timed impulses in one direction.

Preferably said electromagnetic impulses are so timed that they effect acceleration of the movable body. In one form the successive energisations of the solenoids are such as to produce a reciprocation of the movable body (e.g. a reciprocation over a long path).

It is known that if a free magnetic core

is movable within a single solenoid of about the same length (or comparable length to said core) the tendency, on energisation of the single solenoid, would be to bring the core into a mid-position in relation to said solenoid. If now a second solenoid be arranged in tandem with the first and if the first be de-energised and the second energised, the tendency will be for the core to move to a mid-position in relation to the second solenoid. If the magnetic core be of such an axial length as to overlap more than one solenoid, it is possible to impart a linear movement to the core. Assuming that there were four solenoids, A, B, C, D, arranged in tandem, i.e. co-axially, and that the core is within solenoid A which is energised, then by successively de-energising A but energising B, de-energising B but energising C, de-energising C but energising D, the core can be moved in the A—D direction and *vice-versa*. The device of the general type indicated may be used in conjunction with other known mechanical elements (such as springs, ports, valves, relays or tools).

The solenoids may be of equal or unequal ampere-turns in accordance with requirements. The solenoids may be wound independently or they may be wound upon a common former.

The solenoids may be wound on the wall of an actual chamber such as a cylinder, which chamber may be made of any suitable non-magnetic material such as glass, rubber, hard-vulcanised rubber, plastics, earthenware, porcelain, compressed fibre or the like.

It will be appreciated that the chamber may in cross-section be circular, rectangular, triangular, polygonal or of any other desired form.

It is easier to carry out this invention by using D.C. excitation for the solenoids, but A.C. excitation can be employed if the dimensions of the core and the excitation of the solenoids be suitably chosen.

The switch means for energising in succession the plurality of solenoids arranged in tandem may be actuated

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manually, mechanically, hydraulically, electrically or otherwise. For example, a succession of excitations such as A, B, C, D, D, C, B, A, may be effected by a rotary switch resembling the distributor of an automobile engine. Such a rotary switch can be actuated by hand or by clockwork or by a little electric motor, the current for which is switched on at the same time as the current for the solenoids. Hydraulic methods of actuating a rotary switch may take various well-known forms.

The nature of this invention will be appreciated from a description of different examples of its practical application.

In some forms of pump it is desirable to have no normal pump mechanism such as cranks, gearing, mechanical drive, valve gear and the like. Indeed it is desirable to have a plain conduit within which a reciprocating body may effect the pumping action. In one example of this invention a liquid conduit is of circular cross-section and has within it a hollow cylindrical plunger of magnetic material such as soft iron, and at one part of the plunger (say at one end) a one-way flap valve. The conduit is made of non-magnetic material and is embraced by any required number of solenoids arranged coaxially in tandem. Assuming that there are six solenoids, A, B, C, D, E, F, coupled up to the contacts of a rotary switch in a D.C. circuit, it is a simple matter to arrange the timing so that the solenoids are energised in succession (in one sense) in the order, A, B, C, D, E, F, and then energised in the opposite sense in the order, F, E, D, C, B, A, and the result is that the flap valve in the plunger is closed when the plunger is moving in one direction and is open when the plunger is moving in the opposite direction so that the liquid is impelled along the conduit without any other pump than that provided by said plunger.

There are a number of hammers and similar tools where a blow has to be

struck on an actual tool part rapidly and repeatedly. Such conditions occur not only in mining or boring machinery but also in delicate instruments such as certain dental instruments. It will be readily appreciated that a freely-movable core actuated by a succession of solenoids as above indicated can be used as a hammer in such apparatus.

Turning to projectiles, it is sometimes desirable in a toy or in a weapon to discharge a projectile with considerable speed and by the use of a projectile of magnetic material (or containing magnetic material) freely movable in a "barrel" embraced by a series of solenoids as above indicated, it is possible to discharge the projectile from the "muzzle" of such a barrel. This example is an illustration of that form of the present invention in which the movable core is subjected to acceleration. For this purpose the timing of the successive excitations, and the ampere-turns in the successive solenoids are so selected as to ensure such acceleration.

The invention is applicable to a wide variety of uses such as the operation of switch gear, control gear, operation of doors, bells, signalling and indicating devices, or musical instruments.

Although it is not preferred, it is possible to couple the movable core to other devices such as cranks and in any case the movable core may be combined with cushioning devices such as springs.

It will be appreciated that the devices of the present invention are peculiarly well-adapted to remote control.

If desired the chamber or cylinder may be "rifled" and the movable body or core may be adapted to engage the rifling so as to be rotated about its axis.

Dated this 18th day of December, 1947.

BOULT, WADE & TENNANT.

111 & 112, Hatton Garden.

London, E.C.1.

Chartered Patent Agents.

## COMPLETE SPECIFICATION

### Solenoid Devices

I, MALCOLM CHRISTIE BRITAIN, a British Subject, of Kidbrooke, Ridge Way, High Wycombe, Buckinghamshire, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to improvements in solenoid devices. It is a common requirement in a wide variety of appli-

ances that a linear movement shall be imparted to a movable body such as a plunger, piston, core-piece, valve element, projectile or the like. In particular a movable body of the form of a prism, cylinder or ball may have to be moved within a chamber of uniform cross-section such as a hollow cylinder whose axis is straight or curved. The required motion may be (and generally is) a reciprocation. One object of this invention is to

utilize electric solenoids to control the linear movement of a pump piston (containing magnetic material) through a long path.

- 5 This invention consists of a solenoid actuated pump in which a piston containing magnetic material is movable in a chamber or channel such as a hollow cylinder whose axis is straight or curved, 10 said chamber or channel being of non-magnetic material and embraced by a plurality of electric solenoids arranged in tandem in combination with switch means independent of the piston for energising 15 said solenoids in any desired order of succession so that the said piston receives in succession, electromagnetically a plurality of timed impulses in a controllable order determined by the order 20 of said switching means.

Preferably the successive energisations of the solenoids are such as to produce a reciprocation of the piston (e.g. a reciprocation over a long path).

- 25 It is known that if a free magnetic core is movable within a single solenoid of about the same length (or comparable length to said core) the tendency, on energisation of the single solenoid, would 30 be to bring the core into a mid-position in relation to said solenoid. If now a second solenoid be arranged in tandem with the first and if the first be de-energised and the second energised, the 35 tendency will be for the core to move to a mid-position in relation to the second solenoid. If the magnetic core be of such an axial length as to overlap more than one solenoid, it is possible to impart a 40 linear movement to the core. Assuming that there were four solenoids, A, B, C, D, arranged in tandem, i.e. co-axially, and that the core is within solenoid A which is energised, then by successively 45 de-energising A but energising B, de-energising B but energising C, de-energising C but energising D, the core can be moved in the A—D direction and *vice-versa*.

- 50 The solenoids may be of equal or unequal ampere-turns in accordance with requirements. The solenoids may be wound independently or they may be wound upon a common former.

- 55 The solenoids may be wound on the wall of an actual chamber such as a cylinder, which chamber may be made of any suitable non-magnetic material such as glass, rubber, hard-vulcanised rubber, 60 plastics, earthenware, porcelain, compressed fibre or the like.

- It will be appreciated that the chamber (and the piston) may in cross-section be circular, rectangular, triangular, 65 polygonal or of any other desired form.

It is easier to carry out this invention by using D.C. excitation for the solenoids, but A.C. excitation can be employed if the dimensions of the piston and the excitation of the solenoids be suitably 70 chosen.

The switch means for energising in succession the plurality of solenoids arranged in tandem is actuated, mechanically. For example, a succession of 75 excitations such as A, B, C, D, D, C, B, A, may be effected by a rotary switch resembling the distributor of an automobile engine. Such a rotary switch can be actuated by clockwork or by a little 80 electric motor, the current for which is switched on at the same time as the current for the solenoids. Hydraulic methods of actuating a rotary switch may take various well-known forms. 85

In some forms of pump it is desirable to have no normal pump mechanism such as cranks, gearing, mechanical drive, valve gear and the like. Indeed it is desirable to have a plain conduit within which a reciprocating body may effect the pumping action. In one example of this invention a fluid conduit is of circular cross-section and has within it a hollow cylindrical piston of magnetic material such as 90 soft iron, and at one part of the piston (say at one end) a one-way flap valve. The conduit is made of non-magnetic material and is embraced by any required number of solenoids arranged coaxially 100 in tandem. Assuming that there are six solenoids, A, B, C, D, E, F, coupled up to the contacts of a rotary switch in an electrical circuit, it is a simple matter to arrange the timing so that the solenoids 105 are energised in succession (in one sense) in the order, A, B, C, D, E, F, and then energised in the opposite sense in the order, F, E, D, C, B, A, and the result is that the flap valve in the piston is 110 closed when the piston is moving in one direction and is open when the piston is moving in the opposite direction so that fluid in the conduit is impelled along the conduit without any other pump than that 115 provided by said piston.

It will be appreciated that pumps according to the present invention are peculiarly well-adapted to remote control, and a pump or a series of such pumps 120 may be arranged at desired points in a long pipe line such as an oil pipe line, in order to boost the pressure, for instance to compensate for losses in the line due to friction. 125

There is no hard and fast limit in any dimensions of the devices, the particular requirements of each application device being the determining factor, but:—

- (a) As a generality the movable piston 130

should be not less in length than one and a quarter times the axial length of an energising coil and not greater than twice such axial length.

5 (b) The piston can be moved to and retained in a mid-position in any desired coil by energising only the coils leading to and at the desired coil, then the piston will remain in that position if current is then discontinued.

10 (c) The controlling switch can be remote from the solenoids and the speed of travel of the piston can be completely controlled by such a switch.

15 The coils should be of such length and of such ampere-turns as to produce the required pull for the task in hand. In one complete assembly the various coils may be of equal or unequal ampere-turns.

20 The piston (or piston assembly) may comprise portions of any magnetic material such as solid or hollow iron plungers: again the piston may be laminated or may comprise a bundle of wires or rods; it may be articulated, e.g. built up of washers or rings held together; or it may be in the form of a chain or of a section of woven wire.

The piston need not make a close fit with the walls of the chamber in which it moves nor with the inner walls of the solenoids. However, in certain applications (e.g. where the pump has a one-way valve in the piston) the piston may have a sliding fit within the cylinder or other hollow container in which it moves. Where the piston is hollow and embodies a one-way valve, the valve may be a ball valve, a cone or mushroom valve or a 40 check valve.

Where the piston itself constitutes the moving sleeve portion of a sleeve valve, the other or fixed portion of the sleeve valve will be of non-magnetic material.

45 The manner in which this invention may be performed will be appreciated from the following description, reference being made to the accompanying diagrammatic drawing which does not show the switch means, but is a sectional elevation of a boosting pump which may form part of a pipe line.

Referring to the drawing, three coaxial solenoids 1, 2, 3, are shown surrounding 55 a sleeve 12 of non-magnetic material such as a cylinder or pipe of aluminium or earthenware. The core-piece 13 of iron is in the form of a hollow cylinder having annular rims 14 or piston rings which 60 make a sliding fit with the cylinder 12. The one-way valve is indicated at 15.

A solenoid device of the type above described may be in the form of a pump in which the solenoids surround a valved 65 cylinder of non-magnetic material and

the piston (containing magnetic material) is a solid plunger.

The piston in any of the devices may be protected from chemical attack by the application of a coating (say of glass or a hard plastic).

Specification No. 8371/98 describes a combination with an electro-magnet or a series of electro-magnets of a core of decreasing section preferably by being hollow ended. The current may be sent through several coils in succession by the use of a suitable switch e.g., a conductor mechanically connected to the core and successively connecting the terminals of the several coils to the electric source.

Specification No. 341,850 relates to an electric setting device for registering and calculating machines. It shows a series of co-axial coils in tandem with a single core which acts as an automatic switching device for moving said core to a position predetermined by the movement of a selected key or equivalent.

Specification No. 572,433 describes a sanitary water closet in which the flushing mechanism of the cistern is electrically controlled by the employment of an electric solenoid comprising a plurality of coils which are successively energised and successively cut out of circuit independence on the position of the plunger as the solenoid plunger descends.

Specification No. 378,405 refers to electrically operated servo-brakes and shows a brake mechanism wherein a brake applying lever carries a switch, which, when closed energises in succession a series of coils of increasing power having an axially movable magnetic core.

The magnetic core acts as an automatic switch for the several successive coils.

Specification No. 468,020 describes a double acting electrical pump comprising a solenoid with separate windings adapted to be alternately energised, and a core armature reciprocated as a result of such energising, said armature acting piston fashion at both ends within spaces enclosed by a pair of flexible diaphragms, i.e., one at each end, said spaces containing oil, pumping movements being imparted from said armature to said diaphragms through the medium of said oil.

Specification No. 17949/05 describes an electrically operated reciprocating primary piston, whose spindles act as solenoids in operative solenoid cores, forming a fluid compressor operated by the said piston, and pipe means connected from the said fluid compressor to operate a co-existing movement in a secondary piston, with means connected thereto to

operate a mechanical appliance, substantially as described.

I make no claim to anything disclosed in these specifications.

5 Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

10 1. A solenoid actuated pump in which a piston containing magnetic material is movable in a chamber or channel such as a hollow cylinder whose axis is straight or curved, said chamber or channel being  
15 of non-magnetic material and embraced by a plurality of electric solenoids arranged in tandem in combination with switch means independent of the piston for energising said solenoids in any desired  
20 order of succession so that said piston receives in succession electromagnetically a plurality of timed impulses in a controllable order determined by the order of said switching means.

25 2. A solenoid actuated pump device as claimed in claim 1 in which the successive energisations of the solenoids are such as to produce a reciprocation of the piston.

30 3. A solenoid actuated pump as claimed in claim 1 in which the magnetic material in the piston is of such an axial length as to overlap more than one solenoid.

35 4. A solenoid actuated pump as claimed in claim 1 in which the solenoids are wound upon a common former.

5. A solenoid actuated pump as claimed in claim 1 in which the solenoids embrace a hollow chamber such as a cylinder made of non-magnetic material such as glass, rubber, hard-vulcanised rubber, a mouldable plastic, earthenware, porcelain, compressed fibre or the like.

6. A solenoid actuated pump as claimed in any of the preceding claims in which the switch means for energising in succession the plurality of solenoids is actuated mechanically.

7. A solenoid actuated pump as claimed in claim 1 in which the solenoids surround a valved cylinder of non-magnetic material and the piston is solid.

8. A solenoid actuated pump as claimed in claim 1 in which the solenoids surround a cylinder of non-magnetic material and the piston is a hollow plunger embodying a one-way valve.

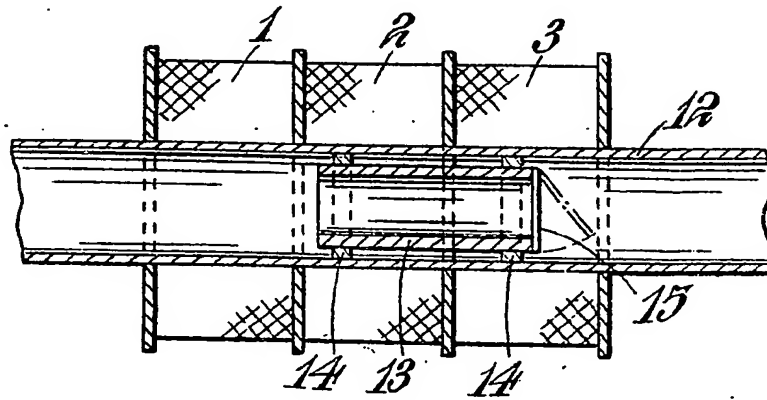
9. A solenoid actuated pump as claimed in claim 1 arranged as a booster in a pipe line for conveying oil or other fluid material.

10. A solenoid device as claimed in claim 1 and substantially as described with reference to the accompanying drawing.

Dated this 15th day of December, 1948.  
BOULT, WADE & TENNANT,  
111 & 112, Hatton Garden,  
London, E.C.1,  
Chartered Patent Agents.

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copies, price 2s. 0d. each (inland) 2s. 1d. (abroad) may be obtained.

*[This Drawing is a reproduction of the Original on a reduced scale.]*



H. M. S. O. (Ty. P.)

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